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Shishido

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(54) **HYDRODYNAMIC PRESSURE BEARING PUMP WITH A SHAFT AND A BEARING HAVING HYDRODYNAMIC PRESSURE GENERATING GROOVES**

(75) Inventor: **Yuji Shishido**, Kanagawa (JP)

(73) Assignee: **Sony Corporation** (JP)

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F04B 17/04 (2006.01)

(52) **U.S. Cl.** **417/423.12**

(58) **Field of Classification Search** 417/423.12, 417/416, 417, 545; 415/111, 112, 229, 170.1
See application file for complete search history.

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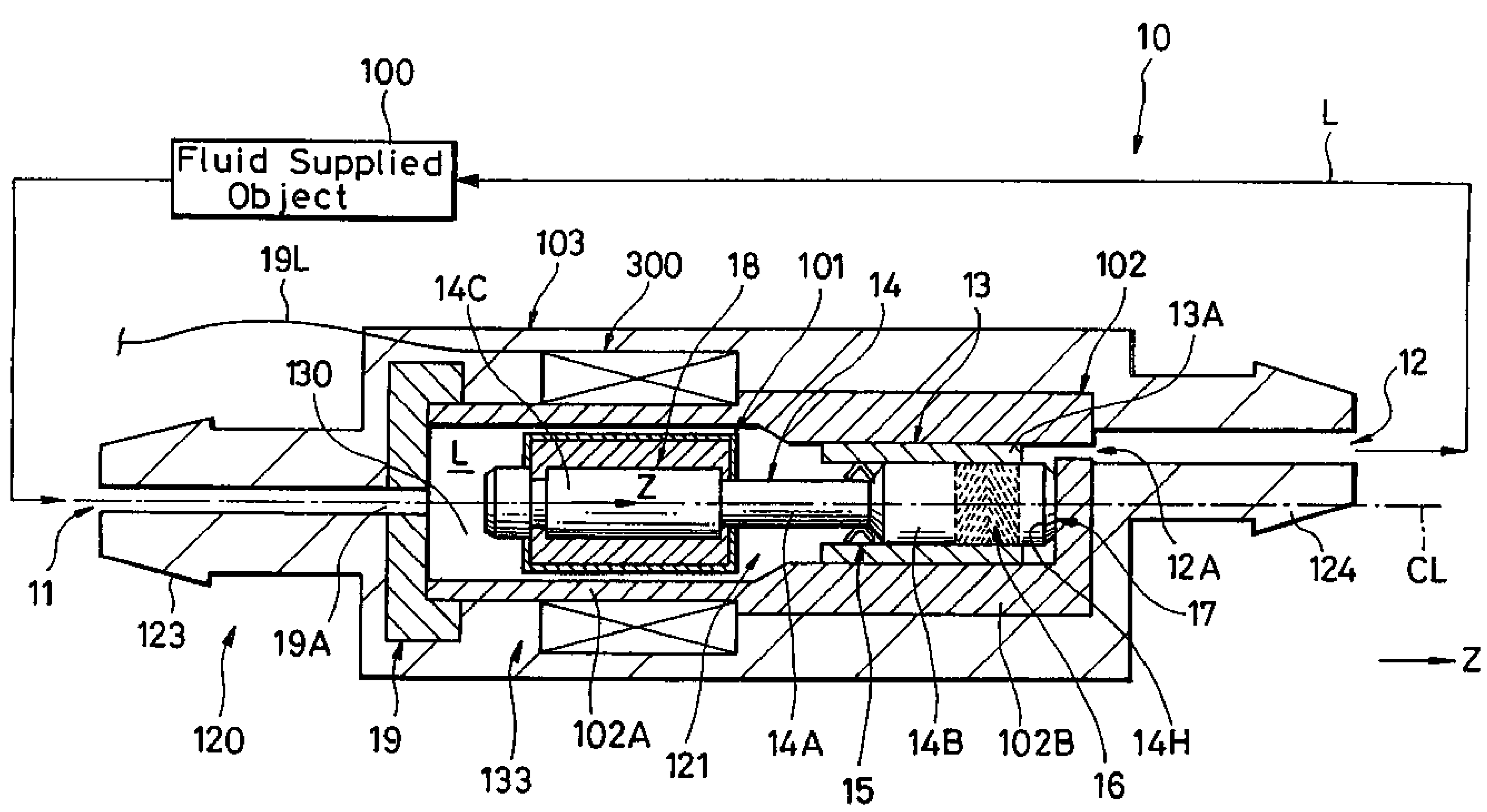
Primary Examiner—Devon Kramer
Assistant Examiner—Vikansha Dwivedi
(74) *Attorney, Agent, or Firm*—Rader Fishman & Grauer PLLC; Ronald P. Kananen

(57) **ABSTRACT**

A hydrodynamic pressure bearing type pump includes a main body having a fluid flow inlet formed at one end portion thereof and a fluid flow outlet formed at the other end portion thereof and a rotating portion disposed within a fluid flow passage of the fluid within the main body to generate hydrodynamic pressure to let the fluid flow into the fluid flow inlet and to let the fluid flow from the fluid flow outlet to the outside. The rotating portion includes a shaft, a hydrodynamic pressure bearing for generating hydrodynamic pressure to let the fluid flow into the fluid flow inlet and to let the fluid flow from the fluid flow outlet to the outside when the shaft is rotated and a rotation force generating portion disposed within the main body to generate rotation force for rotating the shaft when it is energized.

14 Claims, 5 Drawing Sheets



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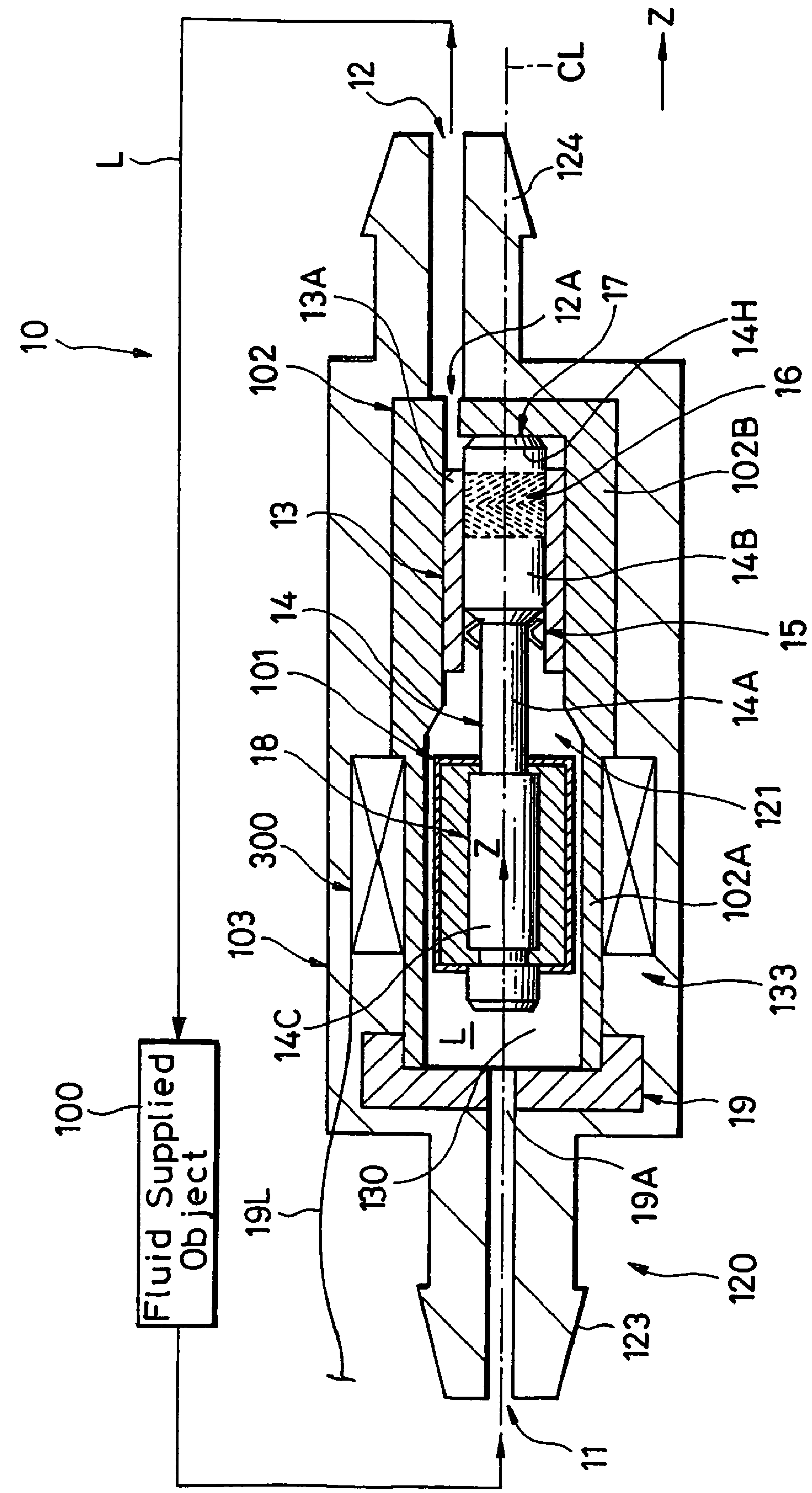

Fluid Supplied Object
100
10
L
12
12A
13
13A
14
14A
14B
14C
14H
15
16
17
18
19
19A
19L
101
102
102A
102B
103
11
120
121
123
124
130
133
300
CL
Z

FIG. 1

FIG. 2

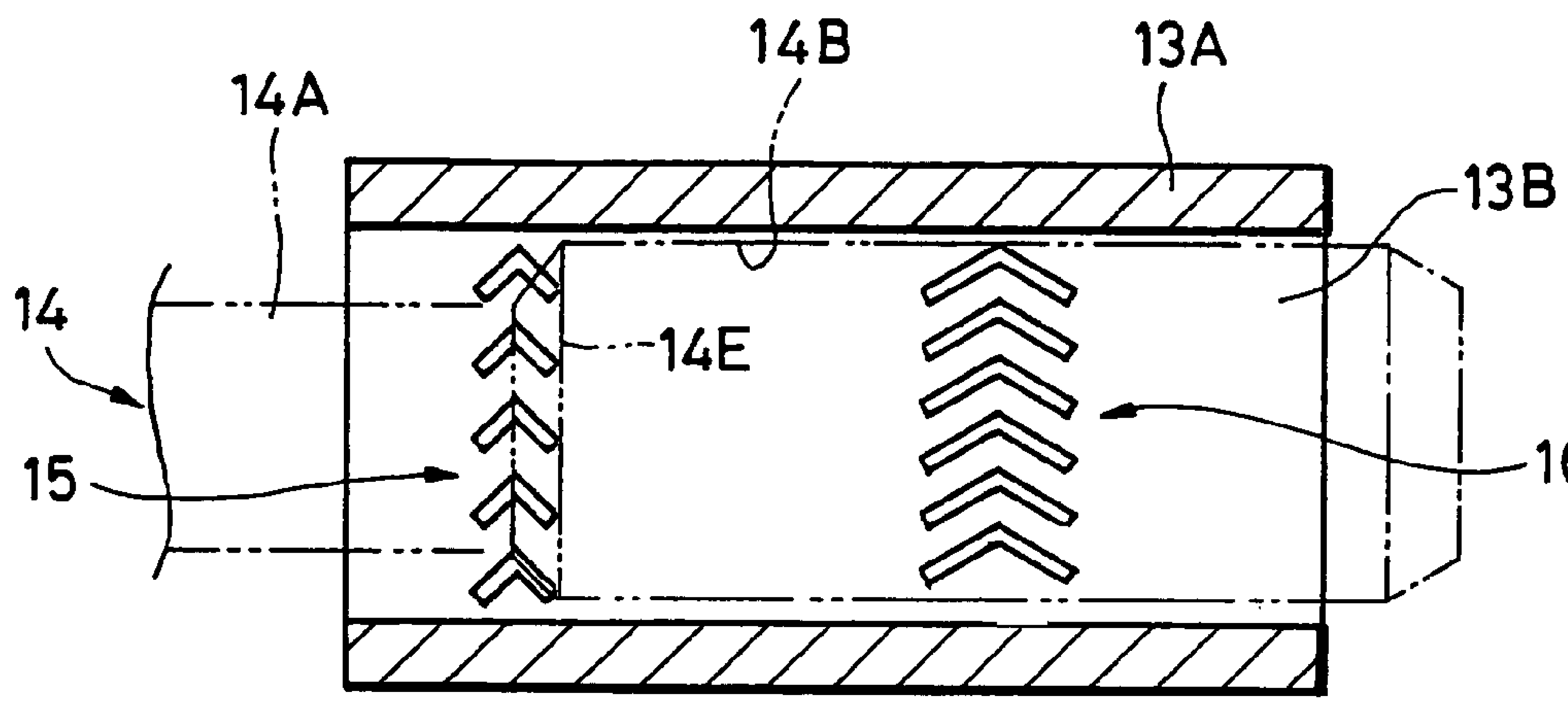


FIG. 3A

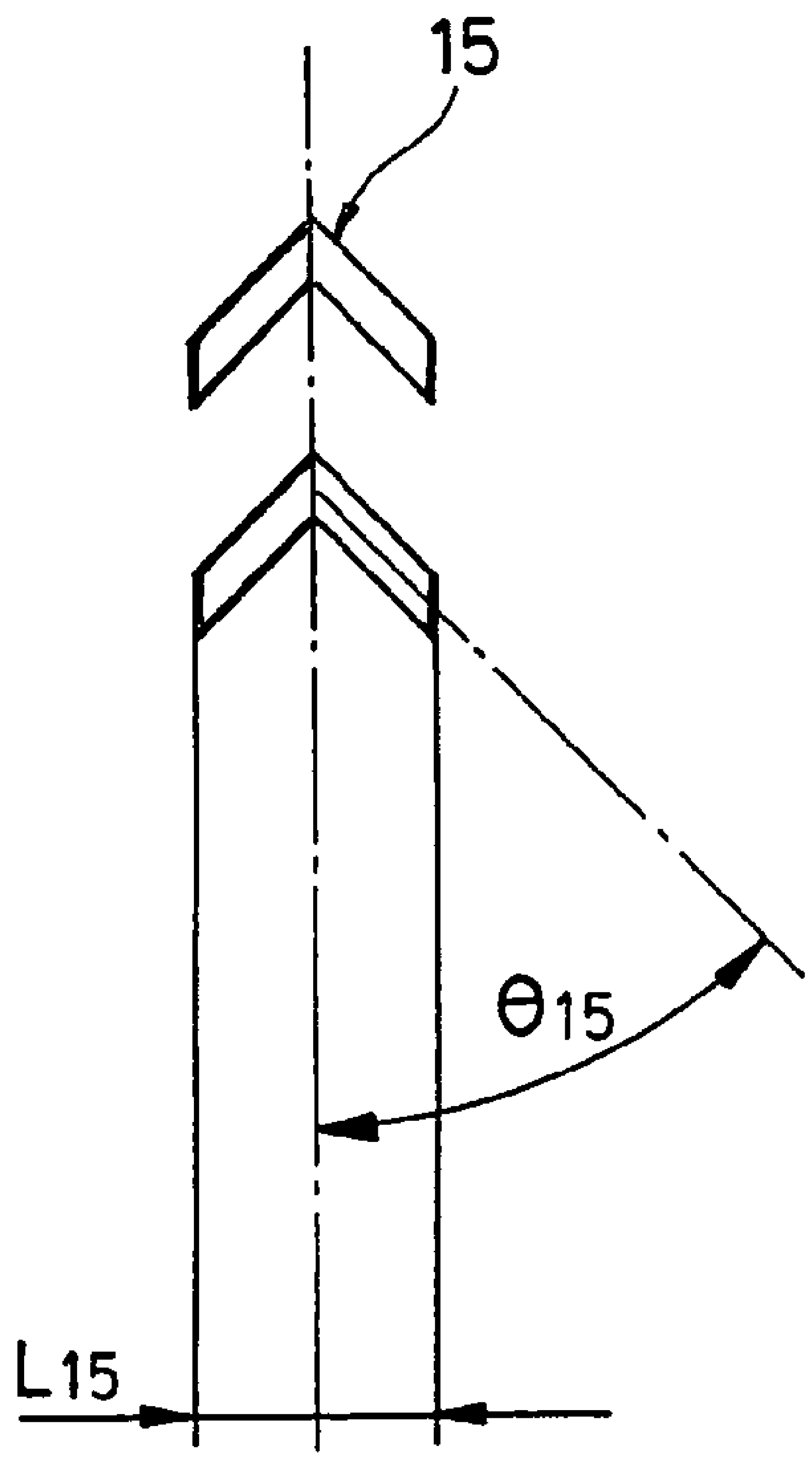
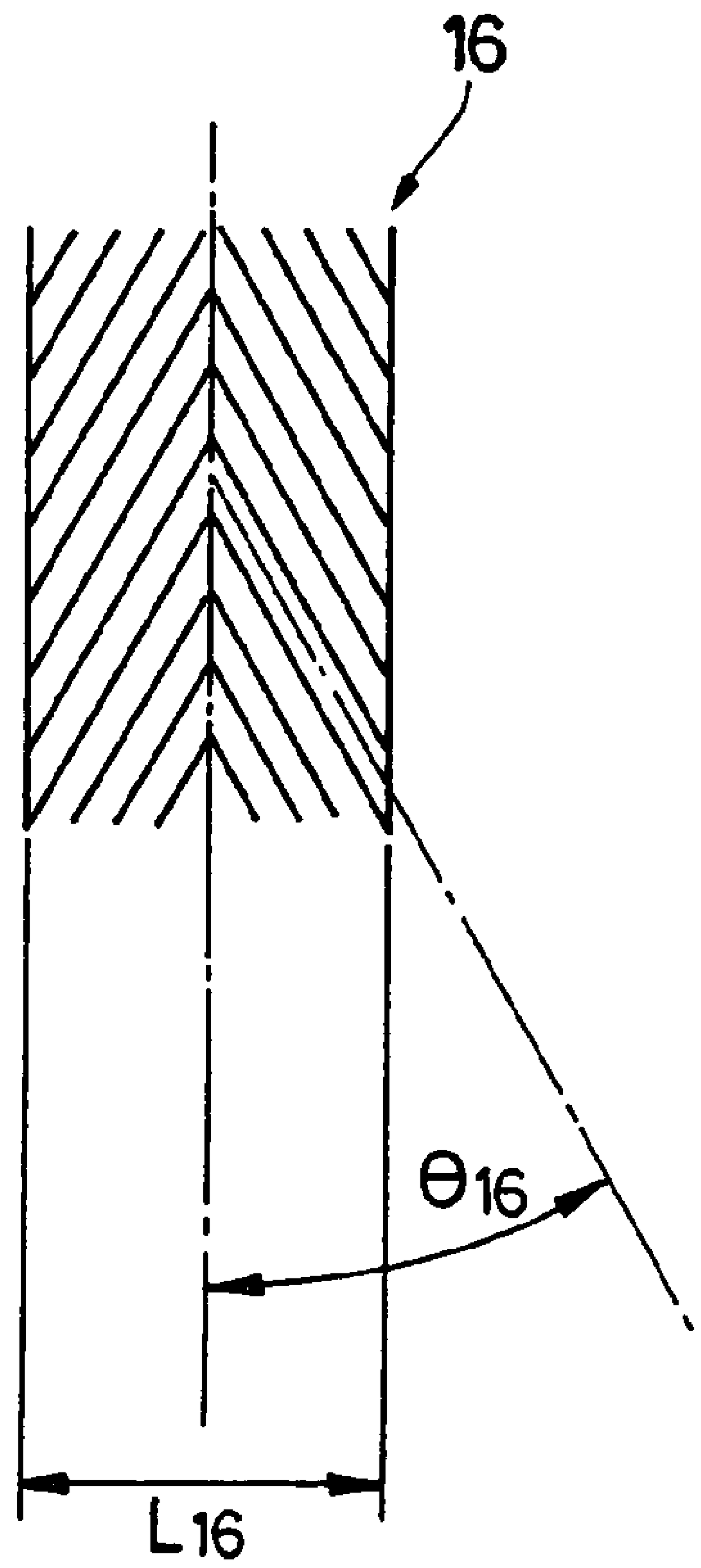


FIG. 3B

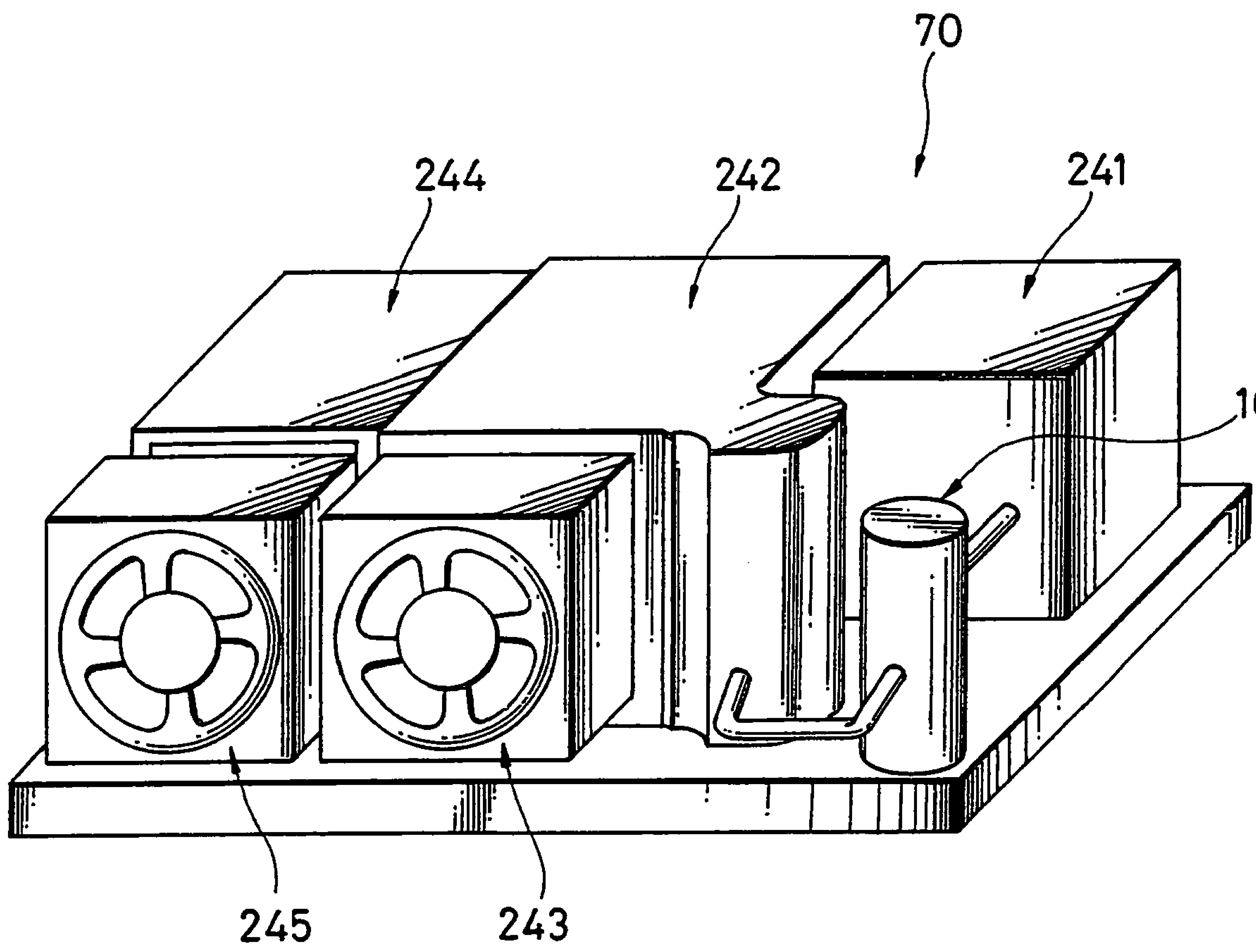


First Hydrodynamic Pressure P15<
Second Hydrodynamic Pressure P16

Flow Inlet Angle θ15 >Flow Inlet Angle θ16

Width L15 <Width L16

FIG. 4



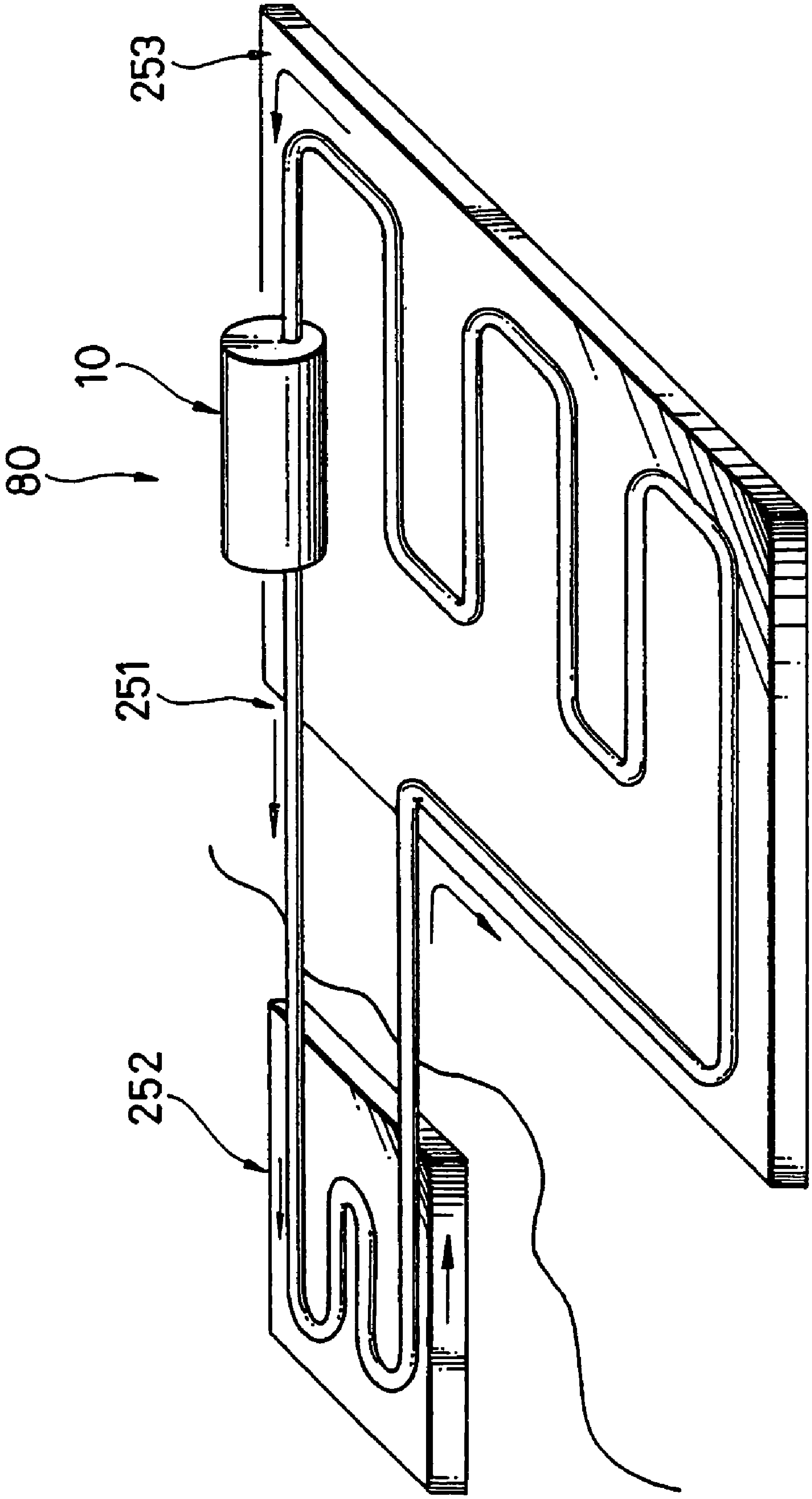
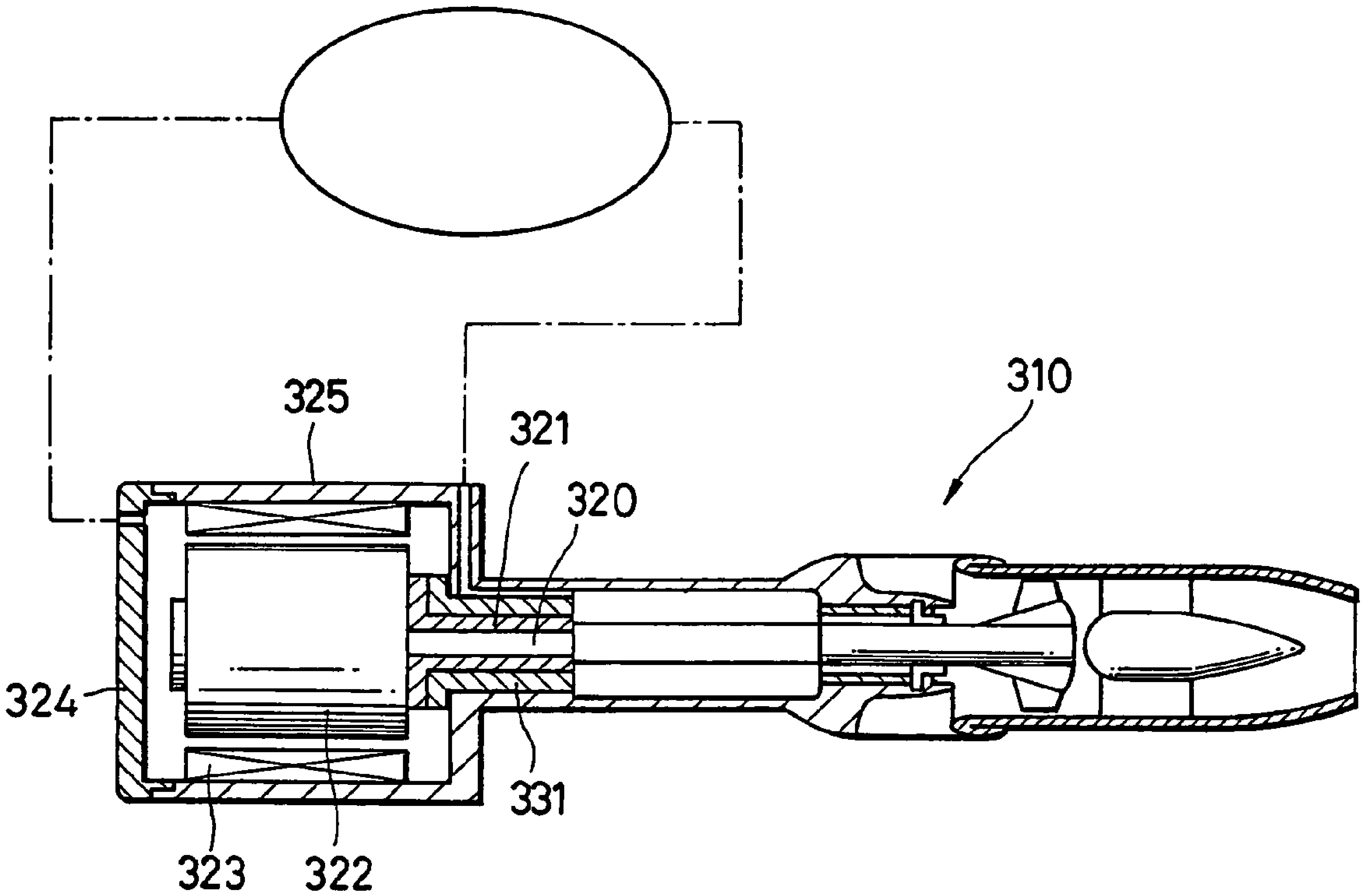


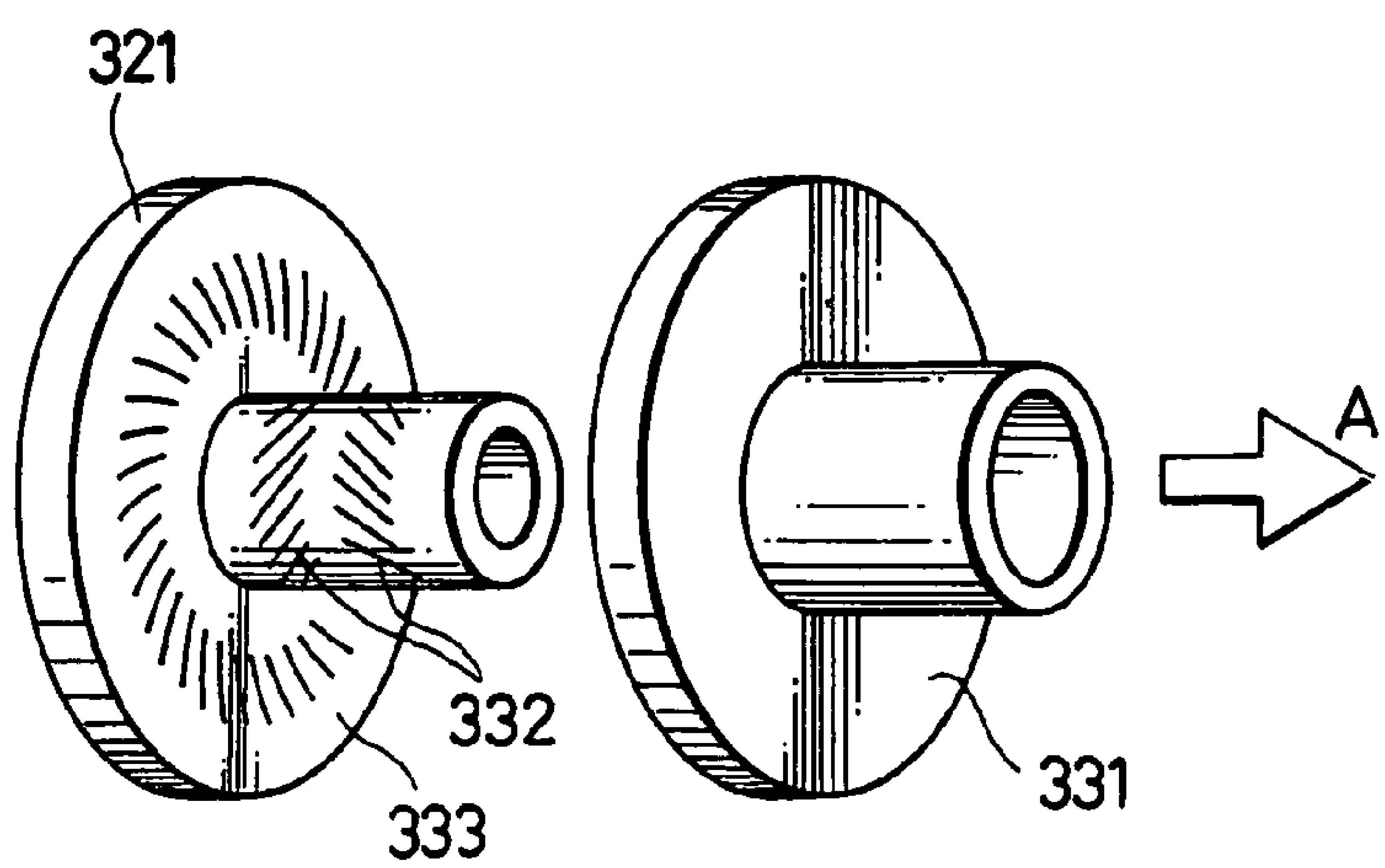
FIG. 5

FIG. 6



Prior Art

FIG. 7



Prior Art

HYDRODYNAMIC PRESSURE BEARING PUMP WITH A SHAFT AND A BEARING HAVING HYDRODYNAMIC PRESSURE GENERATING GROOVES

TECHNICAL FIELD

The present invention relates to a hydrodynamic pressure bearing type pump suitable for the application to a power source for letting fluid flow.

BACKGROUND ART

A pump for letting fluid flow is applied to an artificial heart, for example (see Japanese published patent application No. Hei 6-102087 (pp. 3 to 5 and FIG. 5), for example).

DISCLOSURE OF THE INVENTION

The above-mentioned conventional pump is shown in FIG. **6**, and FIG. **7** shows a hydrodynamic pressure bearing of the conventional pump shown in FIG. **6**.

Referring to FIG. **6**, a conventional pump **310** includes a hydrodynamic pressure shaft **320** with hydrodynamic pressure generating grooves of radial and thrust directions and a rotor magnet **322**. The hydrodynamic pressure shaft **320** and the rotor magnet **322** rotate in unison with each other, and further an armature coil **323** for energizing the rotor magnet **322** also is disposed within a pump diaphragm **324**.

In the conventional pump **310**, the hydrodynamic pressure bearing **321** functions as a pressure generating means for pumping fluid, and it functions as a means for rotatably supporting the rotor magnet **322** in the radial and thrust directions as well.

Also, since the armature coil **323** and the rotor magnet **322** are disposed within the pump diaphragm **324**, it seems that this conventional pump is free from leakage of fluid and hence it seems that this conventional pump is a reliable pump.

The conventional pump **310**, however, encounters with the following drawbacks.

The hydrodynamic pressure bearing **321** mounted on the conventional pump is combined with the rotor magnet **322** and it is rotatably supported by a sleeve **331**. As shown in FIG. **7**, the hydrodynamic pressure bearing **321** comprises one hydrodynamic pressure generating groove **332** for supporting the radial direction and another hydrodynamic pressure generating groove **333** for supporting the thrust direction and hence holds both of the radial and thrust directions.

Since the rotor magnet **322** is supported by the hydrodynamic pressure bearing **333** of the thrust direction, there is a defect that the rotor magnet cannot be reduced in diameter without difficulty.

In order that the hydrodynamic pressure bearing **321** may rotate to generate hydrodynamic pressures to let fluid flow to the outside of the pump as shown by an arrow A in FIG. **7**, a hydrodynamic pressure Pd**333** from the hydrodynamic pressure generating groove **333** of the thrust direction on the fluid entrance side should constantly be smaller than a hydrodynamic pressure Pd**332** from the hydrodynamic pressure generating means **332** of the radial direction on the fluid exit side.

For example, once the hydrodynamic pressure bearing shaft **321** generates the same hydrodynamic pressure, the hydrodynamic pressure bearing shaft only pulls fluid into the inside of the hydrodynamic pressure bearing shaft **321** and is unable to move the fluid. Conversely, if the hydrodynamic pressure Pd**332** on the fluid exit side becomes smaller, then the fluid will flow to the opposite direction.

However, the conventional pump **310** has not yet created the rules to determine a relationship between the magnitudes of generated hydrodynamic pressures, and also it has not yet devised any method for adjusting hydrodynamic pressures.

If it happens that the hydrodynamic pressure Pd**333** on the side of the hydrodynamic pressure generating groove **333** of the fluid entrance side is set to be small so that the fluid may flow to the fluid exit side, that is, in the direction shown by the arrow A, then the sleeve **331** moves from the low hydrodynamic pressure side to the high hydrodynamic pressure side. There is then a defect that it is difficult to support the hydrodynamic pressure bearing **321** at the constant position.

More specifically, in order to use this conventional hydrodynamic pressure bearing type pump actually, such conventional pump needs something for fixing the hydrodynamic pressure bearing **321** to the axial direction, such as to dispose a pivot bearing or to dispose another hydrodynamic pressure generating means on the rear of the hydrodynamic pressure generating groove **333**. However, it is impossible to dispose these means on the conventional pump.

As described above, there is a drawback that the hydrodynamic pressure bearing provided within the conventional hydrodynamic pressure bearing type pump is not suitable for use in actual practice.

Also, while the conventional hydrodynamic pressure bearing type pump is characterized in that the rotor magnet **333** and the armature coil **323** are both disposed in the inside of the pump, it is natural that the armature coil **323**, which is frequently made of a silicon steel or the like, should be energized with application of an electric current. Therefore, this armature coil tends to gather rust and it is not suitable for locating such armature coil in the liquid.

In addition, the rotor magnet **322** also is frequently made of a metal and there is a large possibility that the rotor magnet will rust. Hence, it is not suitable that such rotor magnet is disposed in the liquid.

Further, according to the conventional hydrodynamic pressure bearing type pump, the outer wall of the pump is composed of a combination of a plurality of members such as the cylindrical portion **325** and the diaphragm **324** in order to dispose the motor within the pump. However, it is difficult to perfectly tightly-close the portion in which the cylindrical portion **325** and the diaphragm **324** are fastened together in order to prevent liquid from being leaked from the pump. Hence, the conventional pump becomes unreliable.

Therefore, it is an object of the present invention to provide a hydrodynamic pressure bearing type pump in which the above-described problems can be solved, in which a shaft rotates to generate hydrodynamic pressures to freely rotate the shaft in the radial direction, in which a hydrodynamic pressure bearing can reliably generate fluid pumping pressures and which can be miniaturized.

According to the present invention, there is provided a hydrodynamic pressure bearing type pump in which a shaft rotates to generate hydrodynamic pressure to let fluid flow. The hydrodynamic pressure bearing type pump includes a main body having a fluid flow inlet formed at one end portion and a flow outlet of the fluid formed at the other end portion and a rotation portion located within a fluid passage of the fluid within the main body and which generates hydrodynamic pressure to let the fluid flow from the fluid flow inlet to the fluid flow outlet. The rotation portion includes a shaft, a hydrodynamic pressure bearing for generating hydrodynamic pressure to let the fluid flow from the fluid flow inlet to the fluid flow outlet and a rotation force generating portion disposed within the main body and which rotates the shaft when it is energized. The above-described hydrodynamic pressure bearing includes a first hydrodynamic pressure generating groove formed at the position near the fluid flow inlet and a second hydrodynamic pressure generating groove formed at the position near the fluid flow outlet. The hydrodynamic pressure bearing type pump is characterized in that hydrodynamic pressure generated from the first hydrodynamic pressure generating groove with respect to the radial direction when the shaft rotates is smaller than second hydrodynamic pressure generated from the second hydrodynamic pressure generating groove with respect to the radial direction.

In the present invention, the main body includes the fluid flow inlet formed at one end portion thereof. The main body includes the fluid flow outlet formed at the other end portion thereof.

The rotating portion is disposed within the fluid passage to let fluid to flow within the main body. The rotating portion generates hydrodynamic pressure to let fluid flow from the fluid flow inlet and to let fluid flow to the outside from the fluid flow outlet.

The hydrodynamic pressure bearing of the rotating portion generates hydrodynamic pressure to let fluid flow into the fluid flow inlet and to let fluid flow from the fluid flow outlet to the outside when the shaft of the rotating portion rotates. The rotation force generating unit is a driving unit located within the main body and which rotates the shaft when it is energized.

The hydrodynamic pressure bearing includes the first and second hydrodynamic pressure generating grooves. The first hydrodynamic pressure generating groove is formed at the position near the side of the fluid flow inlet. The second hydrodynamic pressure generating groove is formed at the position near the side of the fluid flow outlet.

First hydrodynamic pressure that the first hydrodynamic pressure generating groove generates with respect to the radial direction is smaller than second hydrodynamic pressure that the second hydrodynamic pressure generating groove generates with respect to the radial direction.

Thus, the hydrodynamic pressure bearing plays the role of rotatably supporting the shaft in the radial direction and it plays the role of generating fluid pumping pressure as well. More specifically, since the first hydrodynamic pressure is smaller than the second hydrodynamic pressure, the hydrodynamic pressure bearing is able to reliably generate pumping pressure to let fluid move from the fluid flow inlet through the fluid flow outlet to one direction so that fluid can flow reliably.

Since the hydrodynamic pressure bearing plays the role of rotatably supporting the shaft in the radial direction and it plays the role of generating fluid pumping pressure as well, the hydrodynamic pressure bearing type pump can be miniaturized.

Also, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, an end portion of the above-described shaft is supported to the thrust bearing located within the main body so as to become rotatable in the thrust direction.

In the present invention, the end portion of the shaft is supported to the thrust bearing located within the main body so that it can rotate in the thrust direction.

As a result, the shaft is able to reliably rotate with respect to its axial direction.

Also, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, a width of the above-described first hydrodynamic pressure generating groove with respect to the axial direction of the shaft is small as compared with a width of the above-described second hydrodynamic pressure generating groove with respect to the axial direction of the shaft.

In the present invention, the width of the first hydrodynamic pressure generating groove with respect to the axial direction of the shaft is set to be small as compared with the width of the second hydrodynamic pressure generating groove with respect to the axial direction of the shaft.

According to this arrangement, the first hydrodynamic pressure can be made smaller than the second hydrodynamic pressure.

In addition, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, a diameter of the above-described shaft is smaller at its portion near the fluid flow inlet than a diameter of the above-described shaft at its portion near the fluid flow outlet.

In the present invention, the diameter of the shaft is set to be smaller at its portion near the fluid flow inlet than the diameter of the shaft at its portion near the fluid flow outlet.

Consequently, the first hydrodynamic pressure can be made further smaller than the second hydrodynamic pressure.

Also, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, a groove depth of the above-described first hydrodynamic pressure generating groove is smaller than a groove depth of the above-described second hydrodynamic pressure generating groove.

In the present invention, the groove depth of the first hydrodynamic pressure generating groove is smaller than that of the second hydrodynamic pressure generating groove.

In consequence, the first hydrodynamic pressure can be made further smaller than the second hydrodynamic pressure.

Also, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, the first and second hydrodynamic pressure generating grooves are herring-bone grooves, and a fluid inlet angle of the above-described first hydrodynamic pressure generating groove is large as compared with a fluid inlet angle of the second hydrodynamic pressure generating groove.

In the present invention, the first and second hydrodynamic pressure generating grooves are both the herring-bone grooves. The fluid inlet angle of the first hydrodynamic pressure generating groove is large as compared with that of the second hydrodynamic pressure generating grove.

Consequently, the first hydrodynamic pressure can be made further smaller as compared with the second hydrodynamic pressure.

Also, according to the present invention, in the above-described hydrodynamic pressure bearing type pump, the main body has the diaphragm located therein, the above-described rotation force generating portion includes the armature coil and a magnet to rotate the shaft when the above-described armature coil is energized, the above-described armature coil is located at the outside of the above-described diaphragm within the main body, and the above-described magnet is fixed to the outer peripheral surface of the shaft.

In the present invention, the magnet in the rotation force generating portion is able to rotate the shaft owing to magnetic interaction produced when the armature coil of the rotation force generating portion is energized. The armature coil is located at the outside of the diaphragm within the main body. The magnet is fixed to the outer peripheral surface of the shaft.

In consequence, the armature coil is isolated from fluid by the diaphragm, and hence the armature coil can be prevented from being exposed to the fluid.

Also, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, the magnet has a coating member disposed on its surface to cover the magnet from the fluid.

In the present invention, the magnet has the coating member disposed on its surface to cover the magnet from the fluid. Thus, the magnet can be protected from the fluid.

Also, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, the above-described main body is another diaphragm for covering the circumference of the diaphragm.

In the present invention, the main body is composed of another diaphragm for covering the circumference to the diaphragm.

In addition, according to the present invention, in the above-mentioned hydrodynamic pressure bearing type pump, a cylindrical member of the above-described hydrodynamic pressure bearing is made of a sintered metal and the above-described fluid is lubricating oil.

In the present invention, the cylindrical member of the hydrodynamic pressure bearing is made of the sintered metal and the fluid is the lubricating oil.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a cross-sectional view showing a hydrodynamic pressure generating bearing type pump according to a preferred embodiment of the present invention;

FIG. **2** is a diagram showing part of a bearing portion of the pump shown in FIG. **1** in an enlarged-scale;

FIG. **3**, consisting of FIG. **3**A and FIG. **3**B, are diagrams showing examples of shapes of first and second hydrodynamic pressure generating grooves of the shaft shown in FIG. **2**.

FIG. **4** is a perspective view showing an example of a fuel cell to which the pump according to the present invention is applied;

FIG. **5** is a perspective view showing an example of a CPU cooling device to which the pump according to the present invention is applied;

FIG. **6** is a diagram showing a cross-sectional structure of a pump according to the prior art; and

FIG. **7** is a perspective view showing a hydrodynamic pressure generating portion of the conventional pump shown in FIG. **6**.

BEST MODE FOR CARRYING OUT THE INVENTION

An embodiment according to the present invention will be described below with reference to the accompanying drawings in detail.

Although various preferable limits are imposed upon the following embodiment from a technology standpoint because the following embodiment is a preferred embodiment of the present invention, the scope of the present invention is not limited to the embodiment so long as the present invention is not particularly limited by the descriptions, which limit the present invention, in the following description.

FIG. **1** shows a hydrodynamic pressure bearing type pump (hereinafter referred to as a "pump") according to a preferred embodiment of the present invention.

A pump **10** is a pump to supply fluid L to a fluid supplied object **100**.

This pump **10** serves as a means for supporting rotation of a shaft **14** and serves as a pressure generating means for generating pumping pressure to the fluid L as well.

The pump **10** is provided with a main body **120** and a rotating portion **121**.

The main body **120** includes a first diaphragm **102**, a space forming member **19** and an outermost wall **103**. The outermost wall **103** is a second diaphragm. The outermost wall **103** accommodates therein the first diaphragm **102** and the space forming member **19**.

A fluid flow inlet **11** is bored on one end portion **123** of the outermost wall **103** of the main body **120**. A fluid flow outlet **12** is bored at the other end portion **124** of the outermost wall **103**. Axial directions of the fluid flow inlet **11** and the fluid flow outlet **12** are slightly deviated from each other. Although the fluid flow inlet **11** is extended through the central portion of the axial direction of the main body **120**, the fluid flow outlet **12** is located at the position slightly displaced from the central portion of the main body.

The first diaphragm **102** is a substantially cylindrical member, for example. The first diaphragm **102** includes a thrust bearing **17**. The first diaphragm **102** includes a through-hole **12**A which communicates with the fluid flow outlet **12**.

The first diaphragm **102** is slightly smaller in outer diameter at its portion **102**A on the side of the fluid flow inlet **11** as compared with an outer diameter at its portion **102**B on the side of the fluid flow outlet **12** of the first diaphragm **102**. The first diaphragm **102** forms a fluid flow passage **130** extended within the pump **10**. This fluid flow passage **130** is communicated with the fluid flow inlet **11** of the fluid and the fluid flow outlet **12** of the fluid.

The first diaphragm **102** can be made of a metal such as a brass and a stainless steel or it can be made of a high polymer material such as LCP (liquid-crystal polymer), PPS (polyphenylene sulfide) polyamide, polyimide, PC (polycarbonate) and POM (polyacetal).

The space forming member **19** is an annular member provided on the side of the fluid flow inlet **11** of the fluid. The space forming member **19** has at its center bored a through-hole **19**A to join the fluid flow inlet **11** of the fluid and the fluid flow passage **130**. The space forming member **19** is adapted to reliably prevent fluid from being leaked from the pump and joins the outermost wall **130** and the end portion of the portion **102**A.

Next, the structure of the rotating portion **121** will be described.

The rotating portion **121** is located in the form in which it is sealed into the main body **120**.

The rotating portion **121** includes a shaft **14**, a hydrodynamic pressure bearing **13** and a rotation force generating portion **133**.

The shaft **14** is made of a metal such as a stainless steel or it is made of the above-mentioned high polymer material such as LCP, PPS, polyamide, polyimide and PC. The shaft **14** has a hemispherical surface end portion **14**H formed at an end thereof. This end portion **14**H is supported to a thrust bearing **17** such that it can rotate in the thrust direction. This end portion **14**H is located at the side of the fluid flow inlet **12**.

The shaft **14** includes a first portion **14**A, a second portion **14**B and a third portion **14**C.

The first portion **14**A is formed between the third portion **14**C and the second portion **14**B. A diameter of the first portion **14**A is smaller than those of the second portion **14**B and the third portion **14**C. More specifically, the first portion **14**A is set to be small in diameter at its position near the side of the fluid flow inlet **11** as compared with a diameter of the second portion **14**B at its position near the side of the fluid flow outlet **12**.

The hydrodynamic pressure bearing **13** shown in FIG. **1** includes a cylindrical member **13**A.

The cylindrical member **13**A is fixed to the inner peripheral surface of the first diaphragm **102** with pressure. The cylindrical member **13**A is a member made of a metal such as a brass and a stainless steel or a high polymer material such as LCP, PPS, polyamide, polyimide and PC. This cylindrical member **13**A may preferably be made of, in particular, a sintered metal, and fluid should be lubricating oil or water, for example.

FIG. **2** and FIGS. **3**A and **3**B show the shapes of the first and second hydrodynamic pressure generating grooves **15** and **16**.

The first and second hydrodynamic pressure generating grooves **15** and **16** are formed on the inner peripheral surface **13**B of the cylindrical member **13**A along the circumference direction.

FIG. **2** shows the state in which the first and second hydrodynamic pressure generating grooves **15** and **16** are formed on the inner peripheral surface **13**B of the cylindrical member **13**A with an interval.

As shown in FIG. **2**, the outer peripheral surface of the second portion **14**B of the shaft **14** is faced to the second hydrodynamic pressure generating groove **16**. A stepped portion **14**E is provided between the second portion **14**B and the first portion **14**A of the shaft **14**, and this stepped portion **14**E is faced to the first hydrodynamic pressure generating groove **15**.

It is preferable that the first hydrodynamic pressure generating groove **15** shown in FIGS. **2** and **3**A and the second hydrodynamic pressure generating groove **16** shown in FIGS. **2** and **3**B are both of herring-bone grooves.

As shown in FIG. **3**, a fluid inlet angle θ**15** of the first hydrodynamic pressure generating groove **15** is set to be large as compared with a fluid inlet angle θ**16** of the second hydrodynamic pressure generating groove **16**. In addition, it is preferable that a width L**15** of the axial direction of the first hydrodynamic pressure generating groove **15** is set to be small as compared with a width L**16** of the axial direction of the second hydrodynamic pressure generating groove **16**.

Next, the rotation force generating portion **133** shown in FIG. **1** will be described.

The rotation force generating portion **133** includes a coil **300** and a rotor magnet **18**. The rotor magnet **18** is fixed to the outer peripheral surface of the third portion **14**C of the shaft **14**.

The rotor magnet **18** has a coating member **101** formed on its outer peripheral surface to isolate it from fluid. This coating member **101** may be provided by coating a high polymer material such as LCP, polyamide and polyimide or it may be provided by an outsert molding.

Even when the rotor magnet **18** is made, for example, of a sintered metal such as Nd—Fe—B, Sm—Co, or ferrite and hence it is easily rusted by fluid, since this coating member **101** is formed on the surface of the rotor magnet **18**, if fluid is water, for example, then the rotor magnet **18** can be prevented from being exposed to the water. As a result, the rotor magnet **18** can be prevented from being rusted.

A coil **300** is fixed to the outside of the portion **102**A of the first diaphragm **102**. This coil **300** is sealed into the outermost wall **103**. A lead wire **19**L of the coil **300** is led out to the outside through the outermost wall **103**. Since the coil **300** is located between the first diaphragm **102** and the outermost wall **103** as described above, the coil **300** can be protected from being exposed to the fluid. Accordingly, the coil **300** can be prevented from rusting and hence it is highly reliable.

The rotor magnet **18** is a magnet in which a number of S poles and N poles are magnetized in the circumference direction. When this coil **300** is energized with a predetermined energizing pattern from the outside, the shaft **14** can continue to rotate about the central axis CL within the fluid flow passage **130** by interaction of a magnetic field generated from the rotor magnet **18** and a magnetic field generated from the coil **300**. This central axis CL is extended along the direction Z in which the fluid is to be pumped.

Next, the hydrodynamic pressure bearing **13** shown in FIG. **1** will be described more in detail.

As the shaft **14** is rotated, the hydrodynamic pressure bearing **13** generates pumping pressure to let the fluid L flow into the fluid flow inlet **11** and to let the fluid flow from the fluid flow outlet **12**.

This hydrodynamic pressure bearing **13** acts to pump the fluid from the fluid flow inlet **11** to the side of the fluid flow outlet **12**. In addition, this hydrodynamic pressure bearing **13** functions to rotatably support the shaft **14** with respect to the radial direction as well.

In order to enable this hydrodynamic pressure bearing **13** to demonstrate a fluid pumping action, the following characteristic means have been devised.

First hydrodynamic pressure Pd**15** generated from the first hydrodynamic pressure generating groove **15** shown in FIGS. **2** and **3** is set so as to become smaller than second hydrodynamic pressure Pd**16** generated from the second hydrodynamic pressure generating groove **16**. More specifically, the first hydrodynamic pressure Pd**15** on the side of the fluid flow inlet **11** is set so as to become positively smaller than the second hydrodynamic pressure Pd**16** on the side of the fluid flow outlet **12**.

As a result, the fluid can reliably be moved along the fluid pumping direction Z from the first hydrodynamic pressure of a small value (from the side in which static pressure is high) to the second hydrodynamic pressure of a large value (to the side in which static pressure is low).

In order to set the first hydrodynamic pressure Pd**15** of the fluid flow inlet **11** so as to become reliably lower than the second hydrodynamic pressure Pd**16** on the side of the fluid flow outlet **12**, it is possible to use the following system or a combination of the following systems.

In order that the first hydrodynamic pressure Pd**15** of the first hydrodynamic pressure generating groove **15** may reliably become smaller than the second hydrodynamic pressure Pd**16** of the second hydrodynamic pressure generating groove **16**, the pump **10** shown in FIG. **1** is devised as follows.

(1) As shown in FIG. **3**, the width L**15** of the first hydrodynamic pressure generating groove **15** along its axial direction shown in FIG. **3** is set to be narrower than the width L**16** of the second hydrodynamic pressure generating groove **16** along its axial direction.

(2) As shown in FIG. **3**, the fluid inlet angle θ**15** of the first hydrodynamic pressure generating groove **15** is set to be larger than the fluid inlet angle θ**16** of the second hydrodynamic pressure generating groove **16**.

(3) Depths of the first and second hydrodynamic pressure generating grooves **15** and **16** are set to be different from each other.

In this case, while the depths of the first and second hydrodynamic pressure generating grooves are neither increased nor decreased indiscriminately, the depths of the first and second hydrodynamic pressure generating grooves should be set in consideration of a ratio between a clearance between the shaft **14** and the cylindrical member **13**A of the hydrodynamic pressure bearing **13**, and a relationship between the depths of the first and second hydrodynamic pressure generating groove is of a nonlinear type relationship with a peak value.

(4) The first portion **14**A of which diameter decreases toward the fluid flow inlet **11** is provided on the shaft **14** with respect to the second portion **14**B with the large diameter. As a result, since the clearance between the first portion **14**A of the shaft **14** and the cylindrical member **13**A increases overwhelmingly as compared with the clearance between the second portion **14**B and the cylindrical member **13**A, hydrodynamic pressure generated from the side of the first portion **14**A decreases as compared with that from the second portion **14**B.

The pump **10** according to the embodiment of the present invention has devised special shapes of the hydrodynamic pressure bearing **13** and the shaft **14**. Accordingly, the fluid L shown in FIG. **1** can flow reliably along the pumping direction Z from the fluid flow inlet **11** to the fluid flow outlet **12**. In addition, a thrust bearing **17** is provided on the side of the fluid flow outlet **12**.

More specifically, the thrust bearing **17** plays the role of preventing the shaft **14** from moving from the side in which hydrodynamic pressure is low, that is, from the side of the first hydrodynamic pressure generating groove **15** to the side in which hydrodynamic pressure is high, that is, to the side of the second hydrodynamic pressure generating groove **16**. Therefore, the pump **10** can be used in actual practice with high reliability.

To pump the above-mentioned fluid L in the fluid flow passage **130** along the pumping direction Z can freely be realized by one method or a combination of a plurality of methods. It is not so easy to pull out the coil **300** shown in FIG. **1** from the fluid flow passage **130** through which fluid passes to the outside. Unless a packing at the portion from which the coil **300** is led out from the fluid flow passage is perfect, then fluid will leak from the pump.

However, in the pump **10** shown in FIG. **1** according to the present invention, the coil **300** is located at the outside of the first diaphragm **102** and sealed into the outermost wall **103**. Therefore, the lead wire **19**L can be led out from the coil **300** to the outside through the outermost wall **103** easily with high reliability.

After the space forming member **19** has been provided on the first diaphragm **102**, the outermost wall **103** is formed around the first diaphragm **102** and the space forming member **19**. This outermost wall **103** is made of the high polymer material as described above. The outermost wall **103** has a seamless structure to cover the first diaphragm **102** and the space forming member **19**. Accordingly, except the fluid flow inlet **11** and the fluid flow outlet **12**, the rotating portion **121** can reliably be isolated from the outside, and hence there can be removed a disadvantage such as leakage of fluid.

The first diaphragm **102** is made of a metal such as a brass and a stainless steel or a high polymer material such as LCP, polyamide, polyimide, PC and POM. In this case, if a high polymer material in which temperature required when the outermost wall **103** is molded can fall within a temperature range in which the high polymer material forming the first diaphragm **102** can be used is available, then the first diaphragm **102** and the outermost wall **103** can be formed by a so-called two-step molding method.

It is needless to say that the space forming member **19** may be made of a metal such as a brass and a stainless steel or it may be made of the above-mentioned high polymer material.

The pump **10** according to the present invention can be applied to a fuel cell **70** shown in FIG. **4** and a CPU (central processing unit) cooling apparatus **80** shown in FIG. **5**.

The fuel cell **70** shown in FIG. **4** is provided with the pump **10** according to the present invention. The fuel cell **70** plays the role of a pump to pump liquid hydrogen fuel to the fuel cell system.

This fuel cell system uses the pump **10** to supply hydrogen from a hydrogen storage tank **241** into a reaction tank **242** and lets air flow into a fan motor **243** so that hydrogen may react with oxygen in air to generate electricity.

The above fuel cell system is provided with a control circuit for controlling a quantity of hydrogen and an electric circuit such as a sensor for controlling reaction heat and humidity. The reaction tank **242** is provided with a heat sink **244** to restrain temperature from rising due to reaction heat. Further, the heat sink **244** is cooled by air from a cooling fan motor **245**, and hence cooling effect can be improved.

The fuel cell **70** is provided with the pump of the present invention, and hence it can be miniaturized. In other words, since the hydrogen storage tank can increase in size, it is possible to increase a reaction time.

When the fuel cell generates electricity, the amount of supplied hydrogen should be controlled while intensity of produced heat and humidity are being sensed. The rotary pump **10** according to the present invention is simple in control

FIG. **5** shows the CPU cooling apparatus **80** to which the pump **10** according to the present invention is applied. Cooling liquid such as water is filled into this CPU cooling apparatus **80**. The CPU cooling apparatus **80** is a circulating type cooling apparatus in which cooling liquid is passed through a route **252**, a CPU **252**, a cooling plate **253** and returned to the pump **10** when the pump **10** is driven.

For example, when the CPU cooling apparatus **80** is mounted on a notebook type personal computer, the notebook type personal computer becomes small in size and becomes excellent in cooling efficiency so that an electric current used up by the CPU **252** can decrease.

As described above, the pump **10** according to the present invention can employ a wide variety of materials such as water, liquid hydrogen fuel, antifreezing liquid and cooling oil as fluid.

When the pump of the present invention is used as a pump for a fuel cell, it is used to pump liquid hydrogen and methanol, and it is unavoidable that any liquid used therein can easily corrode a metal. Accordingly, it is desired that the surface of the member which is directly touched with liquid should be made of a high polymer material as much as possible.

According to the embodiment of the present invention, the hydrodynamic pressure bearing type pump includes the hydrodynamic pressure bearing with more than two hydrodynamic pressure generating grooves of the radial direction. This hydrodynamic pressure bearing plays the role of rotatably supporting the shaft with respect to the radial direction and also plays the role of generating pumping pressure for pumping liquid as well. Therefore, the hydrodynamic pressure bearing type pump can be miniaturized.

Since various shapes have so far been devised for the shapes of the hydrodynamic pressure bearing, it is possible to move the fluid to one direction along the pumping direction Z with reliability. Since the shaft **14** is supported by the thrust bearing so that it can freely rotate in the thrust direction, the hydrodynamic pressure bearing type according to the present invention is highly useful in practical use.

The rotor magnet disposed in the fluid has the high polymer material formed thereon by an outsert molding method or a coating method. In addition, the coil is disposed outside the first diaphragm. Accordingly, since both of the rotor magnet and the coil can be prevented from being directly touched with the liquid, the rotor magnet and the coil are difficult to corrode, and the wiring from the coil need not be led out from the inside of the pump to the outside.

The circumference of the pump is sealed by the outermost wall seamlessly, and hence it is possible to provide the highly-reliable hydrodynamic pressure bearing type pump in which fluid can be prevented from being leaked.

As set forth above, according to the present invention, the shaft rotates to generate hydrodynamic pressure to thereby rotatably support the shaft in the radial direction. At the same time, the hydrodynamic pressure bearing can generate fluid pumping pressure with reliability, and it can be miniaturized.

The present invention is not limited to the above-described embodiment.

It is needless to say that the hydrodynamic pressure bearing type pump according to the present invention is not only used to pump fluid in the above-mentioned CPU cooling apparatus and the fuel cell but also it is suitable for use with other kinds of apparatus.

The first and second hydrodynamic pressure generating grooves are formed on the inner peripheral surface of the cylindrical member in the above-mentioned embodiment. However, the present invention is not limited to the above-mentioned embodiment, and it is needless to say that the first and second hydrodynamic pressure generating grooves may be formed on the outer peripheral surface of the shaft.

The invention claimed is:

1. In a hydrodynamic pressure bearing type pump in which a shaft rotates to generate hydrodynamic pressure to let fluid flow, a hydrodynamic pressure bearing type pump comprising:

a main body including an outer housing and an inner housing surrounded by the outer housing, the outer housing having a fluid flow inlet formed at one end portion thereof and a fluid flow outlet formed at the other end portion thereof; and

a rotating portion disposed within a fluid flow passage of said fluid within said inner housing of said main body to generate hydrodynamic pressure to let said fluid flow into said fluid flow inlet and through said inner housing and to let said fluid flow from said inner housing and through said fluid flow outlet to the outside, said rotating portion comprising:

a shaft extending along an axis of rotation and having a first shaft end and an opposite second shaft end, the shaft having a first shaft piece and a second shaft piece integrally connected to each other along the axis of rotation, the first shaft piece having a first shaft piece diameter and a second shaft piece having a second shaft piece diameter being larger than the first shaft piece diameter;

a hydrodynamic pressure bearing connected to the first shaft end and operative for generating hydrodynamic pressure to let said fluid flow into said fluid flow inlet and through said inner housing and to let said fluid flow from said inner housing and through said fluid flow outlet to the outside when said shaft is rotated; and

a rotation force generating portion disposed within said main body to generate rotation force for rotating said shaft when it is energized, the rotation force generating portion including a rotor magnet connected to the second shaft end and a coil embedded into the outer housing and surrounding the rotor magnet and a portion of the inner housing,

said hydrodynamic pressure bearing including:

a hydrodynamic pressure bearing body member having an inner cylindrical surface defining a shaft-receiving hole formed axially therethrough, the shaft-receiving hole sized to slidably and rotatably receive the shaft, the inner cylindrical surface having

a first hydrodynamic pressure generating groove formed at the position near the side of said fluid flow inlet; and

a second hydrodynamic pressure generating groove formed at the position near the side of said fluid flow outlet,

wherein the first shaft piece and the second shaft piece are rotatably received in the shaft-receiving hole such that, as viewed along the axis of rotation, at least a portion of first hydrodynamic pressure generating groove surrounds the first shaft piece and the second hydrodynamic pressure generating groove in its entirety surrounds the second shaft piece.

2. A hydrodynamic pressure bearing type pump according to claim **1**, wherein said shaft has an end portion supported to a thrust bearing within said main body such that said end portion can rotate in the thrust direction.

3. A hydrodynamic pressure bearing type pump according to claim **2**, wherein said first hydrodynamic pressure generating groove is small in width with respect to the axial direction of said shaft as compared with a width of said second hydrodynamic pressure generating groove with respect to the axial direction of said shaft.

4. A hydrodynamic pressure bearing type pump according to claim **2**, wherein said first hydrodynamic pressure generating groove has a depth smaller than that of said second hydrodynamic pressure generating groove.

5. A hydrodynamic pressure bearing type pump according to claim **2**, wherein said first and second hydrodynamic pressure generating grooves are herring-bone grooves and said first hydrodynamic pressure generating groove has a large fluid inlet angle as compared with that of said second hydrodynamic pressure generating groove.

6. A hydrodynamic pressure bearing type pump according to claim **1**, wherein said hydrodynamic pressure bearing has a cylindrical portion made of a sintered metal and said fluid is lubricating oil.

7. A hydrodynamic pressure bearing type pump according to claim **1**, wherein said main body serves for sealing said rotating portion disposed in said main body.

8. A hydrodynamic pressure bearing type pump according to claim **1**, wherein said main body has a diaphragm disposed therein, said rotation force generating portion includes an armature coil and a magnet for rotating said shaft when said armature coil is energized, said armature coil is located at the outside of said diaphragm within said main body and said magnet is fixed to the outer peripheral surface of said shaft.

9. A hydrodynamic pressure bearing type pump according to claim **8**, wherein said magnet has a coating member disposed on a surface thereof to cover said magnet from said fluid.

10. A hydrodynamic pressure bearing type pump according to claim **8**, wherein said main body serves as another diaphragm for covering the circumference of said diaphragm.

11. A hydrodynamic pressure bearing type pump adapted to pump a fluid therethrough, comprising:

a main body extending along a longitudinal axis and including a longitudinally-extending outer housing and a longitudinally-extending inner housing surrounded by and in contact with the outer housing, the outer housing having a longitudinally-extending fluid flow inlet formed at one end portion thereof and a longitudinally-extending fluid flow outlet formed at the other end portion thereof, the inner housing having longitudinally-extending fluid flow passage in fluid communication with and between the fluid flow inlet and the fluid flow outlet;

a shaft extending along an axis of rotation and having a first shaft end and an opposite second shaft end, the shaft having a first shaft piece and a second shaft piece integrally connected to each other along the axis of rotation, the first shaft piece having a first shaft piece diameter and a second shaft piece having a second shaft piece diameter being larger than the first shaft piece diameter;

a hydrodynamic pressure bearing having a hydrodynamic pressure bearing body member having an inner cylindrical surface defining a shaft-receiving hole formed axially therethrough, the shaft-receiving hole sized to slidably and rotatably receive the shaft, the inner cylindrical surface having a first hydrodynamic pressure generating groove formed at the position near the side of said fluid flow inlet and a second hydrodynamic pressure generating groove formed at the position near the side of said fluid flow outlet, the hydrodynamic pressure bearing connected to the first shaft end;

a rotor magnet assembly connected to the second shaft end; and

a coil embedded in the outer housing and surrounding the rotor magnet and a portion of the inner housing in a manner to isolate the coil from fluid communication with the fluid flow passage,

wherein the first shaft piece and the second shaft piece are received in the shaft-receiving hole such that, as viewed along the axis of rotation, at least a portion of first hydrodynamic pressure generating groove surrounds the first shaft piece and the second hydrodynamic pressure generating groove in its entirety surrounds the second shaft piece and

wherein, upon energizing the coil, the shaft, the hydrodynamic pressure bearing and the rotor magnet assembly rotate within the fluid flow passage of the inner housing to generate hydrodynamic pressure sufficient to pump the fluid from the fluid flow inlet, through the fluid flow passage and out of the fluid flow outlet.

12. A hydrodynamic pressure bearing type pump according to claim **11**, further comprising a hemispherical surface end portion connected to the hydrodynamic pressure bearing opposite to the first shaft end.

13. A hydrodynamic pressure bearing type pump according to claim **12**, wherein the inner housing includes a hemispherical surface end support portion extending radially relative to the longitudinal axis, the hemispherical surface end support portion contacting the hemispherical surface end portion when the shaft, the hydrodynamic pressure bearing and the rotor magnet assembly rotate within the fluid flow passage of the inner housing.

14. A hydrodynamic pressure bearing type pump according to claim **1**, wherein first hydrodynamic pressure generated from said first hydrodynamic pressure generating groove with respect to the radial direction is smaller than second hydrodynamic pressure generated from said second hydrodynamic pressure generating groove with respect to the radial direction when said shaft is rotated.

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